# THE TASMANIAN MUDFISH, *GALAXIAS CLEAVERI* SCOTT, 1934, IN VICTORIA

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KOEHN, J. D. & RAADIK, T. A., 1991:12:31. The Tasmanian mudfish, *Galaxias cleaveri* Scott, 1934, in Victoria. *Proceedings of the Royal Society of Victoria* 103 (2): 77–86. ISSN 0035-9211.

*Galaxias cleaveri* Scott, 1934 is recorded for the first time from the Aire River basin in western Victoria, extending the known westerly distribution of the species. The habitat, general biology and behaviour of the species are described and comparisons made with three species of New Zealand mudfish (*Neochanna* spp.). *G. cleaveri* is nocturnal and able to survive periods without free surface water. Large areas of potential *G. cleaveri* habitat have been destroyed in Victoria, and the preservation of freshwater wetland habitats is essential to the survival of the species in this State, where a conservation status of vulnerable remains justified.

THE TASMANIAN MUDFISH, *Galaxias cleaveri* Scott, a member of the southern hemisphere family Galaxiidae, is a scaleless salmoniform fish first described from Tasmania in 1934 although specimens had been dug up at Strahan in western Tasmania in 1900 (Hall 1901, Scott 1934). The species was considered endemic to Tasmania until 1980 when specimens were discovered on mainland Australia (Jackson & Davies 1982). In the 56 years since its discovery *G. cleaveri* has been recorded only spasmodically, an indication that it is rare in terms of distribution and abundance. Consequently little is known of the general biology and ecology of this species; indeed, not until 1986 did anyone report that it possesses a marine larval stage (Fulton 1986). In the present paper we highlight the presence of *G. cleaveri* in Victoria and provide updated information to help further work and the development of management strategies.

Detailed descriptions of *G. cleaveri* were given by Andrews (1976), McDowall & Frankenberg (1981) and Cadwallader & Backhouse (1983), and the last authors provided a colour photograph. Even so, workers less skilled in the taxonomy of fish may experience difficulty in distinguishing *G. cleaveri* from the broad-finned galaxias, *Galaxias brevipinnis* Günther, and the mountain galaxias, *Galaxias olidus* Günther, which may occur within the same river system.

The following morphological features may be used as a simplified guide to distinguishing adult *G. cleaveri* from *G. brevipinnis* and *G. olidus* (Fig. 1).

1. Anal fin slightly behind origin of dorsal fin in *G. cleaveri*.
2. Shape of dorsal and anal fins: low, rounded to ovoid, elongated posteriorly in *G. cleaveri*.
3. Shape of caudal fin: rounded to truncated in *G. cleaveri*.
4. Shape of flanges on caudal peduncle: large, long and raised in *G. cleaveri*.
5. Shape of pectoral fins: large and rounded in *G. cleaveri*.
6. Small head in *G. cleaveri*.
7. Size of eyes: small in *G. cleaveri*.
8. Large long tubular nostrils: more pronounced in *G. cleaveri*.

Morphological similarities are exhibited with three species of New Zealand mudfish (McDowall & Whitaker 1975, McDowall 1990): the Canterbury mudfish, *Neochanna burrowsius* (Phillipps) (Skrzynski 1968, Cadwallader 1975); the brown mudfish, *N. apoda* Günther (Eldon 1968, 1971); and the black mudfish, *N. diversus* Stokell (Thompson 1987, McDowall 1990). In habitat and habits *G. cleaveri* shows similarities to these species and to the dwarf galaxias, *Galaxiella pusilla* (Mack) (Backhouse & Vanner 1978, Beck 1985, Humphries 1986).

## DISTRIBUTION

### *Previous records*

*G. cleaveri* has been found to be patchily distributed in coastal areas in the north, south and west of Tasmania (Andrews 1976, McDowall & Frankenberg 1981, Fulton 1990) but was reported to be absent from Flinders and King

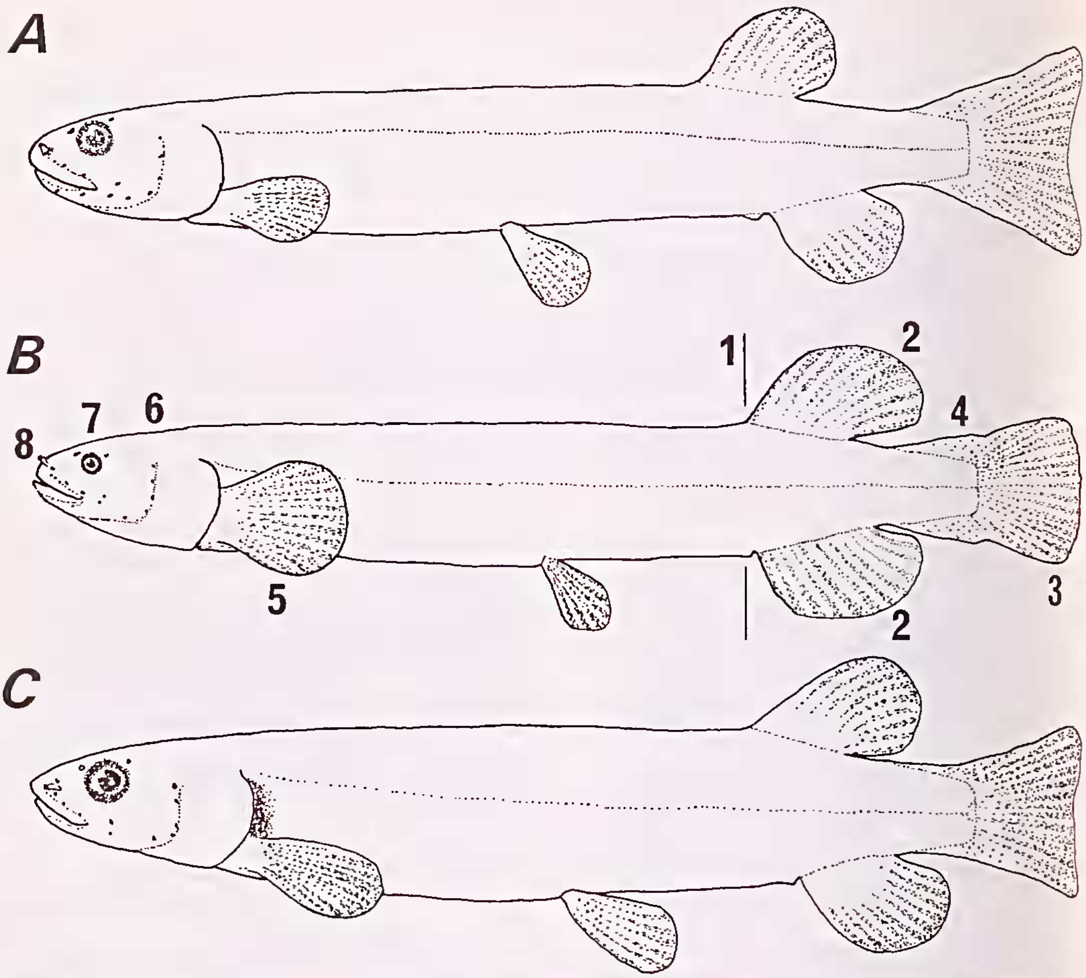


*Figure 1.* Morphological features distinguishing *Galaxias cleaveri* (B) from *G. olidus* (A) and *G. brevipinnis* (C). (After McDowall & Frankenberg 1981.)

Islands in the 1960s (Frankenberg 1967). Andrews (1976) was surprised at the absence of *G. cleaveri* from the Bass Strait islands and mainland Australia, even though at that time he did not know that the species possessed a marine juvenile stage.

*G. cleaveri* was first recorded on mainland Australia in 1980 from the south-east side of Wilsons Promontory, Victoria (Jackson & Davies 1982). In 1983 another individual was recorded from the lower reaches of the Wye River, Otway Ranges (Koehn & O'Connor 1990a; specimen NMV A7594, Department of Ichthyology, Museum of Victoria, Melbourne), extending the known range of the species into western Victoria. These two sites are referred to herein as sites 1 and 2 (Fig. 2, Table 1).

Subsequently, Green (1984) reported *G. cleaveri* from a drain on Flinders Island, Bass Strait (specimens QVM 1984/5/6, Queen Victoria Museum and Art Gallery, Launceston, and NMV A3391). This record completed a distribution pattern coinciding with that of other galaxiid species having a trans-Bassian distribution, namely *G. brevipinnis, G. maculatus* (Jenyns), *G. truttaceus* (Valenciennes) and *Galaxiella pusilla* (Frankenberg 1967).

It is not surprising that *G. cleaveri* has been recorded in only two of the numerous other surveys previously conducted to determine the distribution of freshwater fish in coastal Victoria (see Koehn 1990, Koehn & O'Connor 1990a, Koehn et al. 1991). Sites sampled during those surveys were mostly in streams rather than in

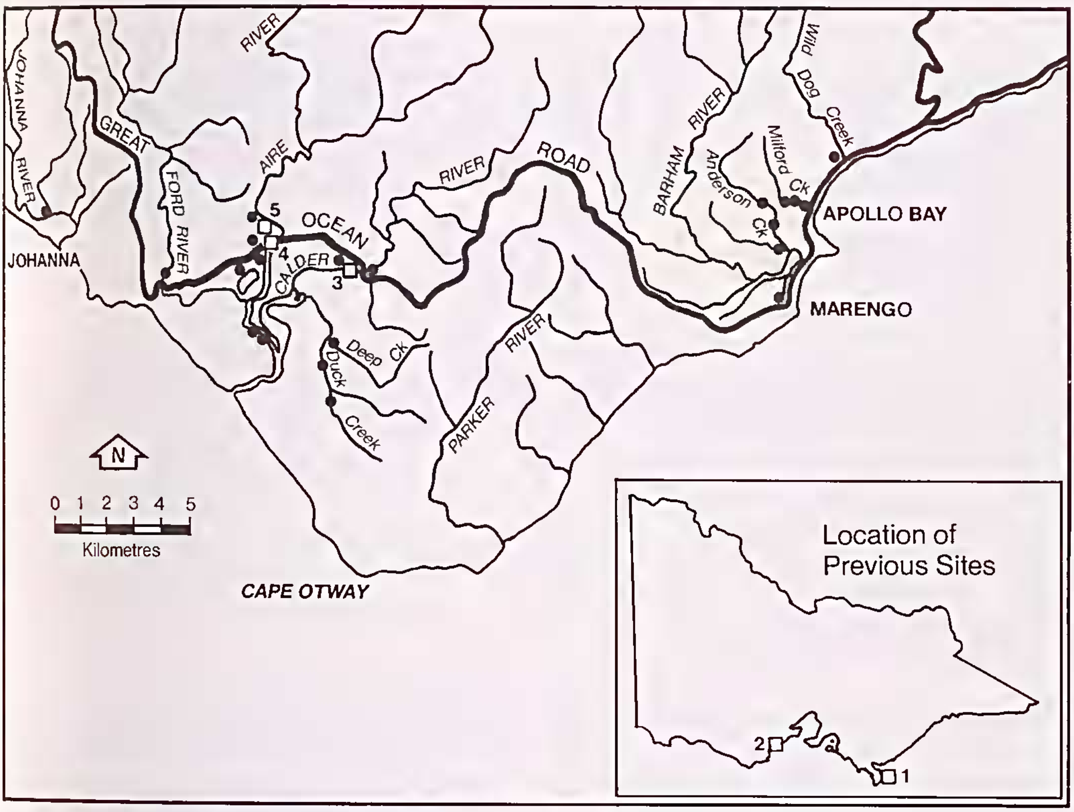


*Figure 2.* Localities from which *Galaxias cleaveri* has been recorded in Victoria (□); ● = additional sites surveyed in this study, but where *G. cleaveri* was not found. Inset: areas where *G. cleaveri* was previously recorded by Jackson & Davies (1982) (1) and Koehn & O'Connor (1990a) (2).

swamp and drain habitats favoured by this species. In addition, specimens of *G. cleaveri* may have been misidentified, particularly before the species was recognised as occurring in Victoria.

*New records*

In 1990 we surveyed likely *G. cleaveri* habitats (small creeks, drains and swamps) in the lowland coastal plains of the Otway Ranges between Skenes Creek (143°43′E, 38°43′S) and the Johanna River (143°23′E, 38°45′S) (Fig. 2). Twenty-four sites were sampled using a Smith Root Model 12 backpack electrofisher and dip nets. Details of all sites sampled and fish species collected are included in Koehn et al. (1991). Eleven specimens of *G. cleaveri* were collected from three sites (sites 3, 4 and 5; Fig. 2 and Table 1) in the Aire and Calder River valleys, 35 km west of the locality on the Wye River where the species was recorded by Koehn & O'Connor (1990a). Specimens have been deposited with the Museum of Victoria: NMV A9512 (Calder River); NMV A9513, A9510 (Aire River, drain); NMV A9511 (Aire River, billabong).

Population density of *G. cleaveri* at the three sites could not be estimated because of the dense vegetation and because of the cryptic and nocturnal habits of *G. cleaveri*. The option of clearing aquatic vegetation to sample more effectively was rejected as all sites were small in area.

*Associations*

All other species associated with *G. cleaveri* (Table 1) are common in the area (Koehn & O'Connor 1990a), are diadromous (with the exception of *Pseudogobius olorum*), and most have been recorded from low-lying swampy habitats. *P. olorum* is usually resident in lower freshwater or estuarine areas as well as in coastal lagoons (Allen 1989), and the specimens of *G. brevipin-*

| Site No. | Waterway | Map No. & Grid Ref. | Altitude (m) | Date Sampled | No. Collected | Total Length Range (mm) | Assoc. Species |
|---|---|---|---|---|---|---|---|
| 1 | Freshwater Creek[A] (tributary) | 8119 493746 | 20 | 29.10.80 | 5 | 37–75* | Sfeel,Cgal |
| | | | | 16.12.80 | 10 | | |
| 2 | Wye River[B] | 7620 514196 | 10 | 14.09.83 | 1 | 93* | Amm,Cgal,Agrayl, Tup,Btr |
| 3 | Calder River (drain) | 7620 178056 | 20 | 17.10.90 | 1 | 90 | Sfeel,Cgal |
| 4 | Aire River (drain) | 7520 147063 | 10 | 31.05.90 | 2 | 56–57 | Sfeel,Cgal |
| | | | | 24.08.90 | 5 | 74–96 | Sgal,Bgal,Bsg |
| | | | | 17.10.90 | 2 | 85–90 | — |
| 5 | Aire R (billabong) | 7520 151068 | 15 | 16.10.90 | 1 | 80 | — |

amm = lamprey ammocoetes, *Geotria australis* or *Mordacia mordax*
Cgal = common galaxias, *Galaxias maculatus*
Sfeel = short-finned eel, *Anguilla australis*
Sgal = spotted galaxias, *Galaxias truttaceus*
*Bgal = broad-finned galaxias, Galaxias brevipinnis*
Tup = tupong, *Pseudaphritis urvillii*
Btr = brown trout, *Salmo trutta*
Agrayl = Australian grayling, *Prototroctes maraena*
Bsg = blue-spot goby, *Pseudogobius olorum*

[A] from Jackson & Davies (1982)
[B] from Koehn & O'Connor (1990a)
* standard lengths

*Table 1.* Summary of site and collection details for *Galaxias cleaveri* in Victoria.

*nis* collected were juveniles migrating upstream to adult habitat.

The association of eels and other species of galaxiids with New Zealand mudfish (*Neochanna* spp.) has been observed by Eldon (1968), and *G. cleaveri* has been associated with other galaxiids and with southern pygmy perch, *Nannoperca australis* Günther (Scott 1936, 1971).

In *G. cleaveri* habitats surveyed on mainland Australia the other resident galaxiid species are essentially free-swimming, whereas *G. cleaveri* is benthic. Thus *G. cleaveri* may face natural interspecific competition or predation only from eels which are also benthic and may occupy similar habitats.

*Biogeography*

The distribution of freshwater native fishes in the Otway region appears to be primarily related to geomorphological conditions that existed during and after the last glaciation 5,000–20,000 years ago (Koehn & O'Connor 1990a). Such conditions restricted non-diadromous freshwater species to the larger Barwon River system to the north and to the Aire and Gellibrand River systems to the south-west, whereas only diadromous species inhabit the short coastal streams. The diadromous lifecycle of *G. cleaveri* accounts for its occurrence in the Wye River.

Frankenberg (1974) suggested that *G. truttaceus* and *G. brevipinnis*, both species with lifecycles similar to that of *G. cleaveri*, may have migrated to mainland Australia from Tasmania when a land bridge existed during the Pleistocene glaciation. A similar migration may be suggested for *G. cleaveri*. Fulton (1986) described a return to fresh water by juvenile *G. cleaveri* and suggested a marine phase in the species' lifecycle (Fulton 1990). The distribution and residency of the larval phase of *G. cleaveri* is unknown, as is the possibility of land-locked populations of the species not possessing a marine life phase. Such populations are known in other normally diadromous galaxiid species (Pollard 1972, Humphries 1989, Fulton 1990, McDowall 1990).

The present distribution of *G. cleaveri* closely conforms to the region encompassed by the land bridge (Wilsons Promontory to Cape Otway). Larvae developing in marine waters would be dispersed more widely and the species would be expected to be more widely distributed. The occurrence of larval galaxiids as far as 700 km from the coast of New Zealand supports the theory of McDowall (1978) that long-range dispersal of diadromous species may occur, as is exhibited by *G. truttaceus* and *G. brevipinnis* which are widespread in Victorian coastal streams (Koehn & O'Connor 1990a, 1990c). The more restricted distribution of *G. cleaveri* suggests that the larvae may be confined to estuaries, although further surveys are needed to elucidate dispersal mechanisms.

## HABITAT

A comprehensive description of the undisturbed habitat at site 1 was given by Jackson & Davies (1982). Site 2 which is also undisturbed is a small steep stream with a pool–riffle sequence draining mountainous forest country. The substrate consisted of cobbles and gravel, the flow was high, fast and turbid, the conductivity was 150 EC and water temperature was 10°C. It is possible that the specimen found at this site had been washed from areas of low-lying pasture during recent rains.

All new sites were characterised as being modified with all riparian vegetation removed, and sites 3 and 4 had also been channelized.

Site 3 is a shallow channel (1 m wide, 0.2 m deep) with a 0.8 m mud substrate and with water 20–30 mm deep draining from a spring in a pastured paddock into the Calder River. At the time of collection (17 October 1990) the channel had recently been excavated and little vegetation was present. Dissolved oxygen concentrations were 5.7 mg/L, pH was 7.0 and conductivity was 680 EC at 8.0°C. On 27 February 1991 the drain was heavily vegetated with a variety of native and introduced species of aquatic and pasture vegetation, the water was 20–30 mm deep, and the mud substrate was 200–400 mm thick.

Site 4 is a shallow drain (0.2–0.4 m deep) with a silt substrate leading from a spring in a cleared paddock into the Aire River. On 24 August 1990 most of the site consisted of a 2 m wide channel together with a larger 15 m × 20 m area, and was densely vegetated with aquatic species. Conductivity was 185 EC at 10°C. On 17 October 1990 dissolved oxygen concentration was 5.6 mg/L, pH was 6.7, and conductivity was 850 EC at 17°C. On 27 February 1991 there was 100 mm of mud and a little water up to 20 mm deep in cattle hoof prints in the channel. The larger area had shrunk to 3 m × 20 m with up to 100 mm of water and 300 mm of mud. Sections of the drain often become dry during summer but other sections always remain moist due to an underground spring (D. Denney pers. comm.).

Site 5 is a small billabong (60 m × 5 m × 0.8 m deep) about 30 m from the Aire River. No flow was apparent and the substrate was silt with dense aquatic vegetation. On 16 October 1990 the water was dark tannin in colour and had a dissolved oxygen concentration of 4.0 mg/L, pH of 6.4 and conductivity of 190 EC at 16.5°C. One specimen of *G. cleaveri* was collected from just inside a large log lying in the water. On 27 February 1991 the site was completely dry, a condition not unusual for this season (D. Denney pers. comm.).

All sites are at low altitudes (a maximum of 20 m above sea level) and close to the sea (a maximum of 8.5 km from the sea but only 3 km from brackish water). Except for site 2, all sites had no discernible flow and had mud or silt substrates and dense aquatic vegetation. Although Andrews (1976) considered that *G. cleaveri* tolerated brackish water, all our specimens were collected from fresh water. The drain leading from site 3, however, flowed into reaches of the Aire River which are known regularly to contain an estuarine salt-wedge under low flow conditions (J. Koehn pers. obs.).

The presence of *G. cleaveri* at these sites is consistent with its occurrence elsewhere in swamps, drains and semi-permanent waters. *G. cleaveri* was collected from stagnant pools in Tasmania (Andrews 1976) and from a drainage system usually dry in summer on Flinders Island (Green 1984). Fulton (1986) also recorded *G. cleaveri* from a dry section of the Esperance River in Tasmania. In New Zealand three species of mudfish, *Neochanna burrowsius, N. apoda* and *N. diversus*, have also been described as specialised to life in swamps, creeks and drains that tend to dry up in summer (Eldon 1968, 1978, 1979a, McDowall 1990).

Scott (1934) described *G. cleaveri* as one of the most specialised galaxiids in having adopted a mode of life suited to such habitats. Such adaptation and an association with low altitude, swampy habitats is likely to indicate a high degree of dependance on the presence of appropriate habitats. Collection of the species in Victoria from disjunct and highly modified areas containing introduced vegetation suggests that these populations may be remnants of a larger population that once existed when suitable habitats were more widespread.

## BEHAVIOUR

We kept four *G. cleaveri* from site 3 in a glass aquarium (0.36 × 0.45 × 0.10 m) containing a silt substrate and vegetation from the site. The behaviour and position of the fish were observed at intervals throughout each day for three weeks, and at 5 minute intervals for 1 hour during one night.

Generally the fish were inactive during the day, resting either on the substrate or amongst vegetation, and were difficult to locate because of their colour and cryptic habit. Individuals spent time resting either on the substrate wherever cover was available, or amongst dense weed just below the water surface. In both situations, several individuals shared the same cover and were in physical contact with each other. This behaviour is similar to that described by Eldon (1969) in *Neochanna apoda* which is also territorial and aggressive to other species in aquaria (Eldon 1968). Individuals of *G. cleaveri* exhibited no such aggressive behaviour to each other or to individuals of *Galaxias maculatus* or *G. truttaceus* which were placed into the aquaria at different times. At night *G. cleaveri* were more active, continually moving around open areas "browsing". At least two of the fish were in open areas at each observation. They immediately retreated into the vegetation when exposed to either white or red light but had always reappeared in the unvegetated areas by the next observation.

Our observations indicate that *G. cleaveri* is a nocturnal, cryptic species which often inhabits the aquatic vegetation rather than the substrate. Other species of galaxiids reported to be nocturnal are *Neochanna apoda* (Eldon 1968), *Galaxias brevipinnis* (Glova & Sagar 1989a), and *Galaxias vulgaris* Stokell (Glova & Sagar 1989b).

## AESTIVATION

Scott (1934) gave details of the ability of *G. cleaveri* to aestivate, though under unnatural conditions. This ability has been noted by several other authors (Fletcher 1907, Hall 1901, Fulton 1986) though their descriptions mainly concern recovery of aestivating individuals. Fulton (1986) provided photographic evidence of *G. cleaveri* aestivating during mid-summer under a rock at least 10 m from free water.

McDowall & Pusey (1983) reported aestivation in *Lepidogalaxias salamandroides*, and aestivation of *Galaxiella pusilla* was suggested by McDowall & Frankenberg (1981). Humphries (1985) tested this suggestion by maintaining specimens of *G. pusilla* in an aquarium for 36 days whilst lowering water levels and maintaining oxygen concentrations at less than 5 ppm. Fish survived on the surface of the mud and in a small hole for several days in the absence of surface water. McDowall (1990) presented evidence of the ability of the New Zealand mudfishes *Neochanna burrowsius* and *N. apoda* to survive dry periods, though both Eldon (1978) and Meredith (1985) concluded that these species do not exhibit true aestivation during which the individual becomes torpid and the normal rate of metabolism decreases.

We investigated whether burrowing and aestivation could be induced in *G. cleaveri* by placing two individuals (101 mm and 78 mm TL) into a glass aquarium ($0.3 \times 0.62 \times 0.3$ m) containing a substrate of soil and mud, a large flat rock at one end, dense aquatic vegetation in the middle, and a piece of log at the other end. The water level was lowered artificially, and heating and illumination were provided during the day by an incandescent globe. On day 10 some tunnelling in the middle section of the tank was observed, and one fish was seen lying near the water surface where it spasmodically gulped water and air. On day 14, when the water level had fallen to 10 mm above the substrate, one fish was resting in a vertical shaft in the mud with its head just protruding. On day 22 neither fish could be seen and no surface water remained, though water was present in the opening of the shaft. Later on the same day the heads of both fish were positioned in the shaft opening and their bodies were under the mud in horizontal tunnels. On day 25 a series of smaller openings were observed in a line directed away from the large shaft, presumably along the horizontal tunnels. On day 31 there was no water in the pit of the large shaft, the mud substrate had begun to dry, and one *G. cleaveri* had its head protruding from the tunnel into the shaft below the surface of the substrate. On day 32, after 5 days without any free water, the fish in the tunnels stopped moving. On day 42 when the substrate had dried to only 30 mm thick the two *G. cleaveri* were seen through cracks in the dry mud lying in the tunnels. The tank was then slowly rehydrated, and the fish recovered movement and emerged when the mud became soft. They both immediately fed on earthworms and showed no ill effects from surviving in stagnant water for 14 days and without surface water for another 14 days.

Whilst not physiologically confirming the ability of *G. cleaveri* to aestivate, our study shows that the species can survive periods without free surface water by burrowing into the substrate.

## LIFECYCLE

Two male *G. cleaveri* collected at site 4 on 31 May 1990 were in a ripe spawning stage (Pollard 1972), whereas individuals collected on 24 August 1990 were all spent or undeveloped, indicating a winter spawning. These observations are consistent with those of Andrews (1976) who reported fully developed eggs in a specimen of *G. cleaveri* examined in Tasmania during May. After ageing whitebait returning to freshwater as approximately 2 months old, Fulton (1986) suggested that *G. cleaveri* spawn during mid-winter, and he believes (W. Fulton pers. comm.) that juvenile *G. cleaveri* return to fresh water during spring along with other galaxiids.

Cadwallader (1975) and Eldon (1979a) concluded that *Neochanna burrowsius* in New Zealand spawns during late winter and early spring in habitats frequented by adults. In contrast, Eldon (1979a) suggested that *N. apoda* spawns during most months of the year, especially when a drought breaks. Because Eldon (1971) found that in an aquarium *N. apoda* deposited eggs above the waterline, he speculated that in the wild the species deposits eggs out of the water amongst damp vegetation and detritus. The spawning location of *G. cleaveri* has not yet been found.

Present evidence indicates that *G. cleaveri* is unique amongst galaxiids in possessing the two characteristics of aestivation and diadromy.

## THREATS AND CONSERVATION STATUS

General threats to freshwater native fish in Victoria have been described by Koehn & O'Connor (1990b) who considered habitat removal and alteration a prime reason for the decline of many species. The reliance of *G. cleaveri* on specific habitat would appear to make it susceptible to habitat changes, particularly the loss of wetland habitat.

The maintenance of fish habitats has been recognised as a key issue in management of the State's freshwater fish fauna (Koehn & O'Connor 1990c). Whilst up to one-third of the State's wetlands have been destroyed (DCE 1988), most of the assessments have related only to waterbirds; further assessments in relation to changes to fish habitats are necessary. Corrick (1981, 1982) and Corrick & Norman (1980) assessed coastal wetlands in southern Victoria and assigned them to the following categories.

1. Flooded river flats: land inundated for very short periods following rain or flooding.
2. Freshwater meadows: land with waterlogged soil for up to 3 months each year but where surface water is shallow and transient.
3. Shallow freshwater marshes: land with waterlogged soil throughout the year, and where surface water may be present for 6 to 9 months.
4. Deep freshwater marshes: land inundated to a depth of more than 1 m during years of average or above average rainfall.
5. Permanent open fresh water: water storages and natural lakes deeper than 1 m.
6. Semi-permanent saline wetlands.
7. Permanent saline wetlands.

From our knowledge of the habitats of adult *G. cleaveri*, shallow freshwater marshes (category 3) and deep freshwater marshes (category 4) appear to provide permanent areas of habitat. Flooded river flats and freshwater meadows may be used temporarily by the species during migration of whitebait or migration of adults to estuarine areas. Open fresh water (category 5) is unlikely to be used, particularly if lacking vegetation. There is no evidence to suggest that saline wetlands (categories 6 and 7) provide suitable habitats.

In a study of the Snowy River and Gippsland Lakes catchments, Corrick & Norman (1980) concluded that 25% of shallow and 34% of deep freshwater marshes have been lost. Within the Port Phillip Bay region, valuable wetlands lost include the Edithvale–Carrum–Seaford Swamps (Champion 1977, Donnelly et al. 1985) and the swamps of the lower Yarra and Maribyrnong Rivers (Castelnau 1872, excerpts from a diary kept by J. Flemings reprinted in Shillinglaw 1879, Kenyon 1934, and Ducker 1985). After studying wetlands between Port Phillip Bay and Mt Emu Creek in western Victoria, Corrick (1982) concluded that 79% of shallow and 66% of deep freshwater marshes had been lost since European settlement, an overall loss of 73% of potential *G. cleaveri* habitat. The most extensive habitat loss, however, is in South Gippsland where 95% of the natural freshwater wetland once present has been destroyed (Corrick 1981). South Gippsland also includes the largest areas of potential *G. cleaveri* habitat because it contains coastal-draining wetlands only within 40 km of the coast, unlike the other areas where wetlands extend as far as 150 km inland.

More than 23,000 ha of wetlands have been lost in South Gippsland, including Koo-Wee-Rup, Cardinia and Yallock Swamps, and swamps along the Powlett and Tarwin Rivers.

Corrick (1981) predicted further loss of wetland areas through drainage, clearing, cultivation and flood mitigation and irrigation works. His prediction appears fulfilled because calculations from recent studies of this area (Corrick unpubl. data) show an overall loss of 99% of potential *G. cleaveri* habitat (shallow freshwater marshes 94%, deep freshwater marshes 99%).

The loss of such large areas of habitat suitable for *G. cleaveri* must be the greatest threat to this species in Victoria in recent times and may account for its fragmented distribution. Similarily, Frankenberg (1974) stated that the range of *G. cleaveri* in Tasmania had undoubtedly been fragmented due to the draining and clearing of swamps.

In New Zealand populations of the three species of mudfish have declined drastically with the loss of habitat due to swamp drainage, development and agricultural practices (McDowall 1990). Whilst concern has been expressed for all three species, Skrzynski (1968) and Eldon (1979b) have questioned whether *Neochanna burrowsius* can survive, especially with continued agricultural modifications. Cadwallader (1975) suggested that preservation of habitat areas through the establishment of reserves should be instigated for this species. A population of *N. burrowsius* established in an artificial pond (Eldon 1988) survived for several years before dying out as a result of a prolonged drought (NZ MAF 1990)

Other threats to adult *G. cleaveri*, such as interspecific competition and predation by introduced trout, *Salmo trutta, Oncorhynchus mykiis* or redfin, *Perca fluvialitis*, are unlikely to be major, especially in swampy habitats with poor water quality unsuitable to these species. *G. cleaveri* whitebait may be subject to predation, however, whilst migrating upstream. Habitat disturbance and competition from other introduced species such as carp, *Cyprinus carpio*, goldfish, *Carassius auratus*, and tench, *Tinca tinca*, are possible but difficult to assess. Sedimentation is unlikely to affect *G. cleaveri* unless the habitat areas become completely filled.

Because *G. cleaveri* is restricted to a specialised aquatic habitat, climatic changes may have serious impacts, although the impact of the Greenhouse Effect is as difficult to predict as it is for other native species (Burchmore 1990). Lower winter rainfall may affect spawning and particularly access to the sea, and an increase in the tidal limit may alter available wetland habitat for mature *G. cleaveri*.

In a recent review of the conservation status of native fish in Victoria (Koehn & Morison 1990) *G. cleaveri* was listed as vulnerable, a category including "taxa not presently endangered but which are at risk by having small populations and/or by occupying restricted habitats susceptible to rapid environmental change and/or populations which are declining at a rate that would render them endangered in the near future". Although we have documented additional localities for *G. cleaveri*, our results reinforce the rarity of the species. The reductions in available freshwater wetlands and ongoing threats to such habitats justify the retention of *G. cleaveri* in the vulnerable category.

## CONCLUSIONS

*G. cleaveri* is more widespread in Victoria than previously believed, occupying natural and modified habitats along lowland coastal areas, at least from Wilsons Promontory to the western Otways. There is a need for further surveys to determine the range of the species in swampy habitats within and outside of this area, particularly on French Island which contains remnant tea-tree swamp habitat that once existed throughout the Koo-Wee-Rup swamp area and the entire Western Port catchment. The discovery of *G. cleaveri* in this area would strengthen arguments that present populations are remnants of a once much larger, more uniformly distributed population. Collection of whitebait as they ascend coastal streams may also be a useful method of determining *G. cleaveri* distribution (Koehn & O'Connor 1990a).

The behaviour and habitat needs of this species are similar to those of the New Zealand mudfishes. The specific habitat needs of *G. cleaveri* make it particularly susceptible to habitat changes; therefore the massive reductions in suitable freshwater wetland habitats have undoubtedly been the greatest threat to the species. The management and conservation of such wetland areas are vital for the preservation of *G. cleaveri* in Victoria.

## ACKNOWLEDGEMENTS

We thank Bill O'Connor, Damien O'Mahony and Mathew Westaway for field assistance, David Denney for local information, Andrew Corrick for the use of unpublished data and Darwin Evans for his comments on the manuscript. Wordprocessing was completed by Kae

Winch and Irene Prentice. This work was completed as part of the Silviculture Systems Project funded by the Department of Conservation and Environment, Victoria.

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